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Endodontic epidemiology and treatment outcome: general considerations

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Epidemiology, general considerations

Epidemiology is the study of distribution of diseases, their prevalence and determinants in man (1). Consequently, the aim of endodontic epidemiology is primarily to gain knowledge of distribution and prevalence of apical periodontitis and its determinants including treatment outcome in different populations evaluated by presence/absence of apical periodontitis.

Descriptive/analytical epidemiology

Epidemiology may be divided in a descriptive and an analytical part. The former is applied in order to gain knowledge about distribution and prevalence of a specific disease, in this case apical periodontitis, while the latter focuses on factors that may be associated with the disease. Cross-sectional studies are used primarily for descriptive purposes, while cohort and case/control studies are suited for disclosing disease determinants and etiologic factors (Fig. 1).

Associations and causality

Disease determinants include both factors that may be directly (causal factors) and those that may be indirectly (risk factors, predictors) associated with the disease. Consequently, the aim of an epidemiological study is not only to focus on causality, but also to characterise individuals with an elevated probability of having the disease in question. Disease determinants may also be used with some success as risk indicators/predictors of future disease, conditional on the prevailing conditions remaining unchanged during the period in question (2). If these conditions change, the predictive power will be reduced.

Epidemiology vs. experimental and clinical studies

In the endodontic scientific literature the impact of experiments and controlled clinical and descriptive studies of micro-conditions and clinical details is overwhelming. A survey of the three most influential international scientific endodontic journals showed that during the last decade, over 2000 reports dealt with experimental and clinical studies, while only 25 epide-

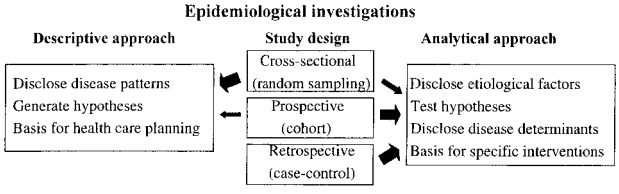

Fig. 1. Design of the three most commonly applied epidemiological study designs, cross-sectional, prospective and retrospective. Cross-sectional studies are best suited for descriptive purposes, while prospective and retrospective may be used for disclosing disease determinants using an analytical approach.

Table 1. A numerical distribution of scientific articles published in three major endodontic journals during the period 1991–2000, sorted according to four main topics of presentation

	Technical[a]	Experimental[b]	Clinical[c]	Epidemiological[d]
Endod Dent Traumatol	114	174	182	16
Int Endod J	250	120	115	7
J Endodont	570	420	301	2
Total	934	714	598	25

[a]Technical includes all kinds of testing of instruments and equipment.
[b]Experimental includes biological and microbiological laboratory-based testing.
[c]Clinical covers all kinds of clinical studies.
[d]Epidemiological which includes the epidemiological studies.

Table 2. An indication of the strength of causal inference from various research designs

Study design	Strength of causal inference	External validity
Experimental	Strong	Weak
Controlled clinical	Strong	Moderate
Epidemiological		
Cross-sectional	Weak	Strong
Case-control	Moderate	Moderate
Cohort	Moderate	Moderate

miological studies could be found (Table 1). Consequently, a dominance of mono-causal thinking prevails, focusing on details related to clinical endodontic activities. The statement made by Rothman & Greenland (3) that: 'The roots of early causal thinking still persist and become manifest in an attempt to find single causes as explanations for observed phenomena', is still highly relevant for clinical endodontics.

It is important to acknowledge that diseases, apical periodontitis included, are in addition influenced by less specific, more distant causes such as dentists' skills and attitudes, behavior and priorities among people and characteristics of their social environment. These factors form causal patterns by interacting in complicated ways and they may be even more important causes of disease than more directly related pathogens (4). Epidemiological studies are the only scientific approach to enlighten such interactions and thereby broaden our concept of health and disease.

Mono-causality vs. multicausality

As mentioned, experiments and controlled clinical studies generally control for as many variables as possible, except the one under study, through the experimental design and consequently become mono-causal in their approach. In addition, controlled clinical studies are usually performed by experts and highly devoted personnel under favorable conditions far from routine clinical reality (no time or economical constraints, strict quality control and well-defined inclusion/exclusion criteria, etc.). The causal impact of such studies is therefore stronger than that of epidemiological studies where multicausality is focused in a probabilistic, not a deterministic, context (Table 2). However, results from epidemiological studies are closer to real life conditions (higher external validity) than experiments and controlled clinical trials. Some consequences of this paradox will be discussed in greater detail at the end of the paper.

What can endodontical epidemiology contribute?

Traditionally, dentistry focuses on treatment of individuals and epidemiology is often considered to belong to public health policy with limited relevance for dental practitioners. However, epidemiological research has more to offer dental practice than results from health surveys. The relevance of the following questions may elucidate this assertion:

- Is the manifestation and nature of a disease as it appears in an individual similar to most other cases, or is it unusual?;
- What are the major causes and contributing factors for a specific condition or disease in society?;
- Are there certain characteristics about the group from which the majority of cases appear?;
- What is the probability that the disease will respond to a specific treatment?

To be answered properly, these questions depend primarily on epidemiological data supplied with information from experimental and clinical research.

Table 3. Prevalence of apical periodontitis (Ap. perio percentage) and apical periodontitis in endodontically treated teeth (Endo-treat. ap. perio percentage) related to country and age. Most, but not all, of the studies referred to applied a random sampling procedure

Study	Country	No. of individuals	Age	Ap. perio percentage	Endo-treatment ap. perio percentage
Bergenholtz et al. 1973 (35) (non-random)	Sweden	240	20–60+	57	31
Hansen and Johansen 1976 (36) (random)	Norway	111	35	30	20
Lavstedt 1978 (37) (random)	Sweden		20–70	45	
Hugoson & Koch 1979 (38) (random)	Sweden	1000	20–70		22–29
Laurell et al. 1983 (39) (random)	Swedn		20–70		25
Hugoson et al. 1986 (18) (random)	Sweden	1000	20–80		23–44
Allard & Palmqvist 1986 (40) (random)	Sweden	500	65	72	27
Petersson et al. 1986 (41) (random)	Sweden	861	20–60		31
Bergstrom et al. 1987 (8) (non-random)	Sweden	250	21–60	47	29
Eckerbom et al. 1987 (9) (non-random)	Sweden	200	20–60 +	63	26
Eriksen et al. 1988 (19) (random)	Norway	141	35	38	26
Odesjo et al. 1990 (42) (random)	Sweden	751	20–80+	43	25
Eriksen and Bjertness 1991 (10) (random)	Norway	119	50	37	44
Imfeld 1991 (43) (non-random)	Switzerland	143	66		31
Petersson 1993 (20) (random)	Sweden	586	20–60		28
DeCleen et al. 1993 (44) (non-random)	Netherlands	184	20–60+	45	39
Eriksen et al. 1995 (45) (random)	Norway	121	35	14	38
Buckley and Spangberg 1995 (46) (non-random)	USA		20–80+		31
Ray and Thrope 1995 (29) (non-random)	USA	985	Adults		39
Saunders et al. 1997 (25) (non-random)	Scotland	186	20–60+	68	58
Marques et al. 1998 (16) (random)	Portugal	179	30–39	26	22
Sidaravicius et al. 1999 (11) (random)	Lithuania	147	35–44	70	35
DeMoor et al. 2000 (17) (non-random)	Belgium	206	18–60+		40
Kirkevang et al. 2001 (26) (random)	Denmark	614	20–60	42	52

Measurements – validity and reliability of criteria used

A requirement for proper performance of epidemiological research is the use of defined criteria for the conditions under investigation including training and calibration of the investigators involved. The criteria should be:

- Measurable;
- Mutually exclusive;
- Meaningful related to the condition under investigation (valid);
- Reproducible;
- Communicable.

The PAI-index system is an example of a set of criteria which fulfils these requirements (5). One of the major advantages of using a well-defined index system is to secure interindividual reproducibility and facilitate comparison between different investigations. The commonly applied success/failure judgment lacks this quality and, in addition, reliability and validity can not be evaluated to the same extent.

Prevalence of apical periodontitis, descriptive studies

With the limited number of epidemiological studies available within endodontology (Table 1), the prevalence and severity of apical periodontitis is known only from selected European countries and from parts of the USA (6). A general trend is that the prevalence of apical periodontitis among 35–45-year-old adults is 30–40% and increasing with increasing age (6, 7). A more detailed survey is given in Table 3. A majority of apical periodontal lesions seem to be located in previously root-filled teeth (7–15). However, a study from Portugal (16) and one from Belgium (17) are among a few that do not support this general trend. In addition, based on a few European studies only, it seems that apical periodontitis is more prevalent than severe marginal periodontitis reported from the same countries (6) (Table 4).

Changes in disease prevalence

There are very few longitudinal or repetitive cross-sectional studies within endodontology reporting time-trends in prevalence of apical periodontitis and other endodontic conditions (10,13,18–21). These studies (all from Scandinavian countries) indicate, however, a reduced prevalence of apical periodontitis and number of root-filled teeth, particularly among the younger part of the populations investigated, and an improved technical quality of the endodontic treatment performed during the last decades. However, a concomitant improvement in results of endodontical treatment is not documented, which is surprising.

Disease determinants studied by analytical epidemiology

From experimental studies it is extensively documented that microbiological infection represents the etiology of apical periodontitis and that incomplete root fillings probably aggravate the possibilities for such infections to persist or re-establish (for review, see Friedman (22)). In a broader context, results from multivariate epidemiological studies indicate that previous endodontic treatment, regular dental care and caries experience appear as strong disease determinants (6, 7, 23). This documentation indicates that dental treatment as it is performed in the societies investigated is not able to effectively prevent or cure apical periodontitis, although the microbiological etiology and how to cope with microbial infection are well established (22). It further illustrates that the treatment principles successfully demonstrated and

Table 4. Prevalence of severe marginal (CPITN-score 4) and apical periodontitis as observed in some Northern European countries (6)

	20–30 years	30–40 years	40–50 years	50–60 years	60 + years
Ap. perio	33%	40%	48%	57%	62%
Marg. perio.	0%	14%	20%	25%	26%

documented from abundant experimental and clinical studies (Table 1) are not utilised properly in general dental practice (6).

Treatment outcome in society

While controlled clinical studies, starting with Strindberg as one of the pioneers (24), show success rates of endodontic treatment of around 90% (for review, see Friedman (22)), epidemiological studies demonstrate that success rates of only 60–75% are commonly found from general practice (6, 7, 14, 15). From the epidemiological studies reviewed it is also extensively documented that the technical quality of the root filling is considered to be the most important determinant. It is, however, a problem inherent in epidemiological studies that the quality of the root fillings is one of the few prognostic factors that can be reliably recorded. Initial diagnosis (pulpitis/apical periodontitis) including size of the lesion, quality of canal preparation, materials used, treatment routines including antibacterial regimen and patients' and dentists' attitudes towards endodontic treatment are among many prognostic factors that remain unknown from epidemiological studies. This may result in an overemphasis on the treatment quality factor, while many of the prognostic factors mentioned may in fact act as undisclosed confounders. In this presentation, we therefore want to focus on some studies where the results deviate from the general trend in an attempt to create alternative hypotheses explaining the observed variation in treatment outcome.

Among the epidemiological publications available, one Lithuanian and one Portuguese study have documented surprisingly good treatment results despite the inferior quality of a majority of the root fillings investigated (11, 16). On the other hand, three Western European studies present very poor results of endodontic treatment (below 50% success), which is claimed to be associated with poor technical quality of the root fillings (17, 25, 26) (Table 5, Fig. 2). What can these unusual studies contribute to the understanding of the association between apical periodontitis and factors related to endodontic treatment? The prognostic criteria presented and discussed by Friedman (22) will be used for further analysis of this question.

Preoperative factors

The initial diagnoses including documentation of eventual re-treatment cases are unknown in all the epidemiological studies. It is therefore impossible to know whether the observed difference in treatment outcome can be due to variation in case selection. The mean age of the participants in all five studies was between 35 and 45 years (Table 5). Even with some range differences it is not likely that variation in age may play a major role in explaining the differences in treatment outcome in the studies presented. Two of three Western European studies (17, 25) used convenience samples (dental school patients), while the Danish study (26) and the other two studies (11, 16) used random samples from defined populations. The observed variation in treatment outcome is therefore probably not due to the sampling methods used.

Prevalence of apical periodontitis and endodontic treatment experience is low in Portugal, but high in the other four populations and consequently not systematically associated with the treatment outcomes observed. The number of remaining teeth is lower in the Belgian sample compared with the others. The suggested explanation that the good Portuguese results were due to frequent extractions of treatment failures in this society is therefore not supported by the present results. Nothing is known about the attitude and skills of dentists regarding endodontic treatment. Patient attitudes to dental treatment differ, however, being more emergency-oriented in Portugal and Lithuania than in the three other countries. This might have resulted in more acute pulpitis cases in

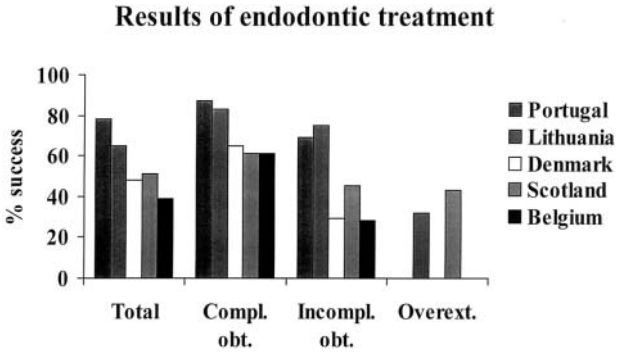

Fig. 2. Results of endodontic treatment from two studies being insensitive to quality variations of the endodontic treatment performed (11, 16) and three (17, 25, 26) where inferior quality was associated with high prevalence of treatment failures.

Table 5. Prevalence of apical periodontitis and treatment outcome in some selected epidemiological studies (11, 16, 17, 19, 25, 26) where the prevalence of apical periodontitis and treatment quality differ

	Norw (19)	Scotl (25)	Portug (16)	Lithu (11)	Belgium (17)	Denm (26)
Age, range	35	20–60+	30–39	35–44	18–60	+20–60
Sample (n)	141	340	179	150	206	614
Prevalence ap.perio.%	30%	68%	26%	70%	63%	42%
Prevalence root fillings %	53%	54%	22%	72%		52%
Remaining teeth (mean)	27	26	25	26	22	26
Adequate endo.%	40%	42%	42%	31%	40%	41%
Success endo.	66%	42%*	78%	65%	39%	48%
Success adeq. endo.	87%	61%*	87%	83%	61%	65%
Success inadeq. endo.	52%	45% *	69%	61%**	28%	29%

*Overall success of endodontic treatment is based on teeth, while figures related to adequate/inadequate endodontic treatment are calculated based on roots, which gives a higher success-rate.
**Inadequate endodontic treatment if over-extended fillings are excluded

these countries compared to the three Western European populations that might have influenced the outcome (27, 28).

Interoperative factors

Apical extent of instrumentation and filling as evaluated from the radiographs varied both within and between the studies. This factor showed an effect opposite to what was expected, which is in fact the rationale for the present analysis. The materials and techniques used are not known, but may be estimated indirectly from what was usually used in the different countries at the time of treatment. Both in Southern and Eastern Europe, formaldehyde-containing materials were, and still are, extensively used (11, 16), while more biocompatible alternatives are the materials of choice in Western Europe. This represents a systematic difference corresponding with the observed variation in treatment outcome.

Postoperative factors

The criteria used for evaluation of the radiographs are similar in two of the three Western European studies (17, 25), but different from the index system (PAI) (5) used in the Danish (26) and the other two studies (11, 16). The cut-off point between a healthy and a diseased tooth was, however, comparable for the two methods and a registration bias may therefore be excluded. Frequency of adequately filled teeth is almost identical in four of the studies, while the Lithuanian sample presents with inferior treatment quality compared to the four other countries (Table 5). This is, however, not in harmony with the observed treatment outcome. A striking and systematic difference is, however, that the results of endodontic treatment seems to be more sensitive to poor technical quality in Denmark, Scotland and Belgium compared to Lithuania and Portugal.

From what is known or can be deduced indirectly from the observations available, there is no reason to believe that the preoperative factors may have played an important explanatory role in the present studies. However, remuneration and patients' and dentists' attitudes to endodontic treatment might have played a role which remains undisclosed. Due to the emergency-oriented dentistry in Portugal and Lithuania, there is also a possible over-representation of vital cases from these populations associated with a better prognosis compared to cases with apical periodontitis (22, 27).

Antibacterial regimens and materials used are some of the intraoperative factors that remain undisclosed from the epidemiological surveys. However, as previously mentioned, potent, toxic formaldehyde-containing dressings and materials are still widely used in Southern and Eastern European countries, while

more biocompatible alternatives are recommended and used in Western Europe. It could be that the latter are more operator-sensitive than the former and that in order to achieve the excellent results (>90% successes) reported from many controlled clinical studies (22), one has to strictly adhere to the recommended treatment principles. The present conclusion should not be considered a recommendation for outdated treatment principles, but an invitation to utilize historical knowledge combined with the present observations to re-evaluate and improve our prevailing treatment routines.

None of the postoperative factors mentioned probably had any substantial impact on the results presented.

Quality of coronal restoration and apical periodontitis

Poor quality of coronal restorations has been considered a possible additional pathway for bacterial penetration and apical infection, adding to the problems associated with poor quality of the root fillings itself. Leakage along root fillings has been extensively investigated *in vitro* (28). Recently an attempt has been made to investigate this hypothesis *in vivo* using an epidemiological approach (*7*, 11, 29–31) (Fig. 3). Ray & Trope (29) documented a clear association between the quality of both coronal and endodontical restorations on treatment outcome in a study on dental school patients in Philadelphia and an overall success-rate of only 18% when both factors were ranked as poor. This pattern was confirmed by Kirkevang et al. (30), while a less clear picture could be detected from a Lithuanian (11) and a Norwegian study (31) (Fig. 3). Two studies have, however, documented that completely lost coronal restorations do not seem to aggravate the apical conditions in root filled teeth (11,17), while restorations including a pulpal post may represent a challenge to apical health (17, 25, 32). In conclusion, a coronal restoration of inferior quality or posts involving the pulpal canal might be conducive to a poor prognosis, but the correlation is not as clear as initially demonstrated by Ray & Trope (29).

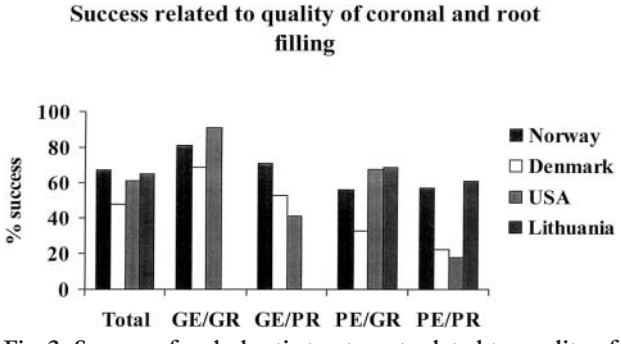

Fig. 3. Success of endodontic treatment related to quality of both coronal and root fillings. As can be seen, endodontic treatment in the Portuguese and Lithuanian studies appears to be more robust to quality variation than was found in the three other studies. In the Lithuanian study, most of the root fillings were of inferior quality and a differentiation in endodontic quality as therefore not been performed.

Causality

In the search for causal evidence, it is important to distinguish between identifying single causes and understanding causal patterns. Rothman & Greenland (3) have defined a sufficient cause as a web of minimal interacting conditions that inevitably produce the disease. This relates directly to the concept of causality which, according to Susser (33), can be divided into a strict and a liberal definition. A strict definition implies that the factor(s) should be directly and actively involved in the disease process, while a liberal definition includes all factors that comply with the concept of association, time order and direction. The strict version complies with experiments and controlled clinical trials which constitute the core of evidence-based dentistry and thereby has a profound impact on clinical routines. The liberal, probabilistic version relates to analytical epidemiology, which is less deterministic and more relevant to real-life conditions. A balanced understanding based on a considered combination of the two alternatives is the most reflective and mature attitude. Bradford-Hill (34) has defined requirements for causation based on observational studies which, in addition to association, time order and direction, emphasise that the factors have to:

- comply with results from true experiments in humans or animals;
- demonstrate difference in strength of association between exposed/unexposed;
- demonstrate dose/effect association;
- verify the cause/effect association as biologically reasonable;
- demonstrate less disease with reduced exposure;

• consider alternative explanations.

These requirements indicate the importance of considering epidemiology, clinical and experimental research as complementary, not mutually exclusive or contradictory, acknowledging the difference in their basic assumptions.

Conclusions

The present epidemiological survey indicates that the good results of endodontic treatment obtained in controlled clinical studies are not achieved in general dental practice. Results from analytical epidemiology supplied with knowledge from experimental and clinical studies emphasize the technical quality of the root fillings as a key prognostic factor. However, factors that are usually not measured and identified may be critical to the outcome of endodontic treatment (27). Joint efforts and communication between all parts of the scientific endodontic community are therefore necessary in order to improve quality and treatment outcome in society.

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